Amendments to the Specification:

Please replace the first paragraph on page 1 with the following amended paragraph:

This application is related to U.S. Patent Application No. [[ ]] 10/068,794, filed concurrently herewith, entitled "MINIATURE CIRCULATOR ARRAY DEVICES AND METHODS FOR MAKING THE SAME" (Attorney Docket No. 020858-000900US), the disclosure of which is hereby incorporated by reference in its entirety.

Please replace the paragraph beginning on page 8, line10, with the following amended paragraph:

Figs. 13A-~~13E~~ 13F illustrate a magnetic processing methodology for obtaining the desired magnetic profile in a magnetic garnet according to an embodiment of the present invention;

Please replace the first (partial) paragraph on page 10 with the following amended paragraph:

plane (plane of Fig. 1C) where the direction of propagation of an incoming light signal is along the z-axis. Hence the optic axis of each of PBS elements 110 and 170 lies in the y-z plane at an angle θ relative to the z-axis, and at 90° relative to the x-axis. For any light traveling parallel to the optic axis, there is no birefringence. Thus, each of the PBS elements are arranged such that the e-beam is refracted along the principal plane (vertically relative to Figs. 1A and 1C), while the o-beam passes straight through along the z-direction. Unless stated otherwise, it is to be assumed throughout this detailed description of specific embodiments that the direction of propagation of incoming light signals is ~~be~~ parallel to the z-axis.

Please replace the first (full) paragraph on page 16 with the following amended paragraph:

Figs. 3A-3D show the elements and operation of another three-port circulator device 300 according to an embodiment of the present invention. The circulator device 300 includes PBS elements 310 and 370, Faraday rotator elements 320 and 360, half-wave plates 330 and 350, GRIN lenses 390 and 395, and Wollaston Prism elements 340 and 345, and is similar to

the circulator device 100. For example, the PBS elements 310 and 370 are each arranged such that their principal planes are parallel to the y-z plane (plane of the drawing of Fig. 3C). In the circulator device 300, however, the relative positions of the half-wave plates and Faraday rotator elements are reversed. That is, in the circulator device 300 a forward z-propagating beam's components first encounter a half-wave plate and then a Faraday rotator element. Such a reversal of position of the half-wave plates and Faraday rotator elements only affects the local polarization states of the component beams and does not change the general operation of the circulator device. For example, as shown in Fig. 3D, a beam's mutually perpendicular polarized components originating from port 2 (bottom trace) first encounter the half-wave plate 350, which rotates both components by 45° in the counterclockwise direction (position H). The beam components, still mutually perpendicular to each other, then encounter oppositely poled regions of the Faraday rotator element 360, which rotate the components by 45° in opposite directions such that they are polarized as an e-beam (x-polarized) relative to the first encountered prism of the Wollaston Prism element 345 (position G). Thus, as with the embodiment in Figs. 1A-1D, the combination of each adjacent pair of Faraday rotator and half-wave plate elements operates to convert mutually perpendicular polarization components into components having parallel states of polarization in a desired orientation. Similarly, each adjacent pair of Faraday rotator and half-wave plate elements convert components having parallel polarization states into mutually perpendicular polarization states.

Please replace the last paragraph beginning on page 16 with the following amended paragraph:

Figs. 4A-4D show the elements and operation of another three-port circulator device 400 according to an embodiment of the present invention. The circulator device 400 includes PBS elements 410 and 470, Faraday rotator elements 420 and 460<u>, GRIN lenses 490 and 495,</u> and Wollaston Prism elements 440 and 445. The Wollaston Prism elements 440 and 445 are arranged similar to the Wollaston Prism elements 140 and 145 of Figs. 1A-1C. It is noted that the circulator device 400 does not include any half-wave plates. Rather, the PBS elements 410 and 470 are each arranged such that the optic axis points in the direction of θ=45° relative to the z-axis and φ =45° relative to the y-axis. In this embodiment, rotation by the first encountered

Faraday rotator element in opposite directions by 45° is sufficient to orient the polarization of the divided beams such that they are both parallel to or perpendicular to the optic axis of the first encountered prism of the first encountered Wollaston Prism element. Similarly, when the parallel polarized beam components emerge from the second-encountered Wollaston Prism element, rotation by the second encountered Faraday rotator element in opposite directions by 45° is sufficient to orient the beams so that they are mutually perpendicular, with one component parallel to the principal plane of the output PBS element.

Please replace the first (full) paragraph on page 17 with the following amended paragraph:

Figs. 5A-5D show the elements and operation of another three-port circulator device 500 according to an embodiment of the present invention. The circulator device 500 includes PBS elements 510 and 570, Faraday rotator elements 520 and 560<u>, GRIN lenses 590 and 595,</u> and Wollaston Prism elements 540 and 545. The PBS elements are arranged such that the principal plane of each lies parallel to the y-z plane. It is noted that the circulator device 500 also does not include any half-wave plates. Rather, the Wollaston Prism elements 540 and 545 are each arranged such that the optic axis of the first encountered prism of the first encountered Wollaston Prism element points in the direction of 45° relative to the x-axis and 45° relative to the y-axis, i.e., the optic axis is in the x-y plane. In this embodiment, rotation by the first encountered Faraday rotator element in opposite directions by 45° is sufficient to orient the polarization of the divided beams such that they are both parallel to or perpendicular to the optic axis of the first encountered prism of the first encountered Wollaston Prism element.

Please replace the last paragraph beginning on page 17 with the following amended paragraph:

Figs. 6A-6D show the elements and operation of another three-port circulator device 600 according to an embodiment of the present invention. The circulator device 600 includes PBS elements 610 and 670, Faraday rotator elements 620 and 660<u>, GRIN lenses 690 and 695,</u> and half-wave plates 630 and 650. The PBS elements 610 and 670 are arranged such that the principal plane of each lies parallel to the y-z plane. The circulator device 600 operates similarly to the Fig. 1 circulator device 100. However, rather than including Wollaston Prism

elements, the present embodiment includes Rochon Prism elements 640 and 645. A Rochon Prism element includes two prisms coupled together, with mutually perpendicular optic axes similar to a Wollaston Prism, but the first encountered prism of a Rochon Prism element is oriented with its optic axis parallel, rather than perpendicular, to the direction of propagation. In a Rochon Prism element, the second encountered prism, with its optic axis at right angles to the first prism, transmits the o-beam without deviation but the e-beam is deflected.

Please replace the second (full) paragraph on page 18 with the following amended paragraph:

Figs. 7A-7D show the elements and operation of a six-port circulator device 700 according to an embodiment of the present invention. The circulator device 700 includes PBS elements 710 and 770, Faraday rotator elements 720 and 760, half-wave plates 730 and 750, GRIN lenses 790 and 795, and Wollaston Prism elements 740 and 745. The arrangement of elements and operation is nearly identical to that of the circulator device 100, with a "stacked" arrangement of two circulator devices similar to the circulator device 100. In the present embodiment, the Faraday rotator elements 720 and 760 each have four oppositely poled regions as shown, with horizontal boundaries (relative to Fig. 7C) between the oppositely poled regions. As shown in Fig. 7C, the top two periodically poled regions of the Faraday rotator elements 720 and 760 are used by the "top" circulator represented by ports 1, 2 and 3, whereas the bottom two periodically poled regions are used by the "bottom" circulator represented by ports 1', 2' and 3'. It should be appreciated that multiple circulator devices similar to circulator device 100 may be stacked in a similar fashion.

Please replace the last paragraph beginning on page 18 with the following amended paragraph:

Figs. 8A-8E show the elements and operation of another six-port circulator device 800 according to an embodiment of the present invention. The circulator device 800 includes PBS elements 810 and 870, Faraday rotator elements 820 and 860, GRIN lenses 890 and 895, and Wollaston Prism elements 840 and 845. The arrangement of elements and operation is nearly identical to that of the circulator device 500, with a "stacked" arrangement of two

circulator devices similar to the circulator device 500. The two "stacked" circulators are arranged such that the two-port end face of one circulator is located proximal the one-port end face of the other circulator. For example, as shown in Fig. 8A, ports 1 and 3 of the "top" circulator are located proximal port 2` of the "bottom" circulator.

Please replace the second (full) paragraph on page 19 with the following amended paragraph:

Figs. 9A-9D show the elements and operation of another three-port circulator device 900 according to an embodiment of the present invention. The circulator device 900 includes PBS elements 910 and 970, Faraday rotator elements 920 and 960, half-wave plates 930 and 950, <u>GRIN lenses 990 and 995,</u> and Wollaston Prism elements 940 and 945. The PBS elements 910 and 970 are each arranged such that its optic axis points in the direction of $\theta = 45°$ relative to the z-axis and $\varphi = 45°$ relative to the y-axis. The Faraday rotator elements 920 and 960 each have a uniform profile (i.e., uniform poling), whereas the half-wave plates 930 and 950 are each etched with a horizontal boundary as shown in Fig. 9C, i.e., a portion of each of half-wave plates 930 and 950 has been removed, while the optic axis of each of the remaining portions is arranged so as to cause a 90° rotation. In this embodiment, each Faraday rotator element rotates the component beams in the same direction, and the beam component interacting with the unetched (shaded) portion of a half-wave plate undergoes a 90° rotation, whereas the beam component interacting with the etched (unshaded) portion passes through with its state of polarization unchanged.

Please replace the full paragraph on page 24 with the following amended paragraph:

Figs. 14A-14C illustrate a cold poling process arrangement according to an embodiment of the present invention. As shown, a U-shaped magnetic core 1610 includes a magnetic poling mold 1620 at one end. The poling mold 1620 is a micro-lithographically defined mold having one or more magnetic micro-tips. In one embodiment, each micro-tip has a width of about 100μm to about 250μm. The garnet is positioned between the soft keeping layer 1630 and the magnetic poling mold ~~1630~~ <u>1620</u>. An electric current sufficient to create the

desired magnetic field strength within the magnetic core 1610 is applied through the electrical coil 1640. As shown in the cross sectional views of the magnetic poling mold 1620 in Figs. 14B and 14C, one (Fig. 14C) or more (Fig. 14B) magnetic tips of magnetic material are interspersed within a non-magnetic material (shaded portions) such that only the magnetic domains coming into contact with the tips have their fields reversed. Thus, with an appropriate arrangement and sizing of tips, the desired periodic poling pattern can be achieved. In one embodiment, as shown in the bottom view of the multi-pole layout in Fig. 14B, thin gaps are cut, or alternatively fused, in the magnetic garnet to delineate and isolate neighboring domains prior to the cold poling process.

Please replace the last paragraph beginning on page 24 with the following amended paragraph:

For the hot poling process step 1550 as illustrated by Fig. 13F, one or more heating beams are applied to the garnet with the appropriate pattern. That is, only those regions desired to be magnetically reversed are heated. In preferred aspects, the heating beams are collimated laser beams. Heating decreases the coercivity of the magnetic garnet so that a smaller magnetic field strength is needed to reverse the heated domains. Thus, a magnet having a field strength, Br, less than the normal (unheated) coercivity of the garnet, but great enough to reverse the heated domains, is positioned proximate the garnet. In this manner, the heated domains are reversed while the unheated domains are unaffected by the magnet. In one embodiment, the beams each have a diameter of about 250μm. It should be appreciated that the garnet may be periodically poled using the hot poling process after the circulator device has been fabricated and integrated with a fiber array. In this case, heat beams can be introduced using the attached fiber array through the other elements of the circulator device, and a magnet can be positioned proximate the circulator device as appropriate.

Please replace the first full paragraph on page 25 with the following amended paragraph:

Returning to the fabrication process of Fig. 12, at step 1440, a PBS layer of desired thickness is grown on the magnetic garnet. In one embodiment, the PBS layer is

deposited using e-beam evaporation, or an ion-beam, in a flux collimating and limiting arrangement 1800 as shown in Fig. 16. According to this embodiment, the magnetic garnet is mounted on a tilted substrate holder 1860 in a high vacuum deposition chamber 1810. Evaporant collimators 1830 direct the material from the source building material 1820 through the slot of plate 1840. Before the growth of the PBS layer, the garnet is preferably AR coated. To obtain a large birefringence, silicon (Si) is used as the source building material 1820 (rather than SiO2) with some fine (<50nm) voids in between. To saturate the dangling bond of the amorphous Si, small amount (5-10%) of H_2 gas is added to Argon gas and pumped into the chamber. The deposition pressure is critical for the fineness control of the Si columnar structure. Germanium (Ge) may also be used as a source material.

Please replace the second full paragraph on page 25 with the following amended paragraph:

To obtain large birefringence, the tilting angle of the substrate (γ) is tuned. In one embodiment, for example, the tilting angle is set at between about 65° and about 70°, and preferably about 65°, to obtain the maximum birefringence. Due to a large tilting of the substrate, non-uniformity of the growing film between the lower and upper part of the substrate becomes a problem since for a point source, the flux density is inversely proportional to the squared distance (R^2) between the source and the substrate. To correct the problem, in one embodiment, substrate holder 1860 is designed to move parallel to the slot of plate 1840 with a varying speed, slower (longer time to collect material) at the upper part and faster (shorter time) at the lower part. After finishing the deposition of the PBS layer 1850, the surface is preferably AR coated to enhance optical transmission and to protect against moisture incorporation into the voids (fine air gaps) in the PBS layer.

Please replace the first paragraph on page 27 with the following amended paragraph

Fig. 17 illustrates another fabrication process, similar to the process of Fig. 12, including the formation of etched half-wave plates according to an embodiment of the present invention. The process starts at step 1910 with a non-magnetic garnet substrate. At step 1920 magnetic garnet is grown by liquid phase epitaxy with the particular garnet film with matching lattice constants of the growing film and the substrate. Then the non-magnetic garnet is removed

by lapping/polishing and the magnetic garnet is poled at step 1930. In step 1940 a PBS layer is deposited on the magnetic garnet and on the opposite side of the garnet a double tilted, half-wave plate (HP) layer is grown by step 1950. A spatial walk-off plate (SWP) polarizer is either grown or cut from a birefringent crystal in step 1960. At step 1970, the half-wave plate is etched to form periodic gaps in the half-wave plate layer and at step 1980 a second half-wave(HP) plate on a second poled magnetic garnet layer with a PBS layer on the opposite is etched with periodic gaps complementary to the gaps of the first half-wave plate. At step 1990 the two half-wave plates, each fixed to its own poled magnetic garnet layer and PBS layer, are mounted on either side of the spatial walk-off plate to form the optical circulator. One notable difference in this process is that, at step 1970, the half-wave plates are periodically etched to produce periodic gaps of desired dimension. In this process, conventional masking and etching techniques are used to obtain the desired etch pattern. It should also be appreciated that, although not shown in Fig. 17, the magnetic garnet may be periodically poled as discussed above with reference to Fig. 12.

Please replace the Abstract beginning at page 39, with the following amended Abstract:

ABSTRACT OF THE DISCLOSURE

Miniature optical devices, including circulator array devices, are fabricated using thin film coating technology. A typical optical device ~~according to the present invention~~ includes two refraction elements arranged opposite each other along a propagation axis and coupled on opposite ends to first and second polarization orientation elements with first and second ~~polarization beam splitter (~~PBS~~)~~ elements are coupled to the first and second polarization orientation elements, respectively. The refraction elements include complementary Wollaston Prism elements or ~~complementary~~ Rochon Prism elements. Each polarization orientation element includes a Faraday rotator element, and in some embodiments, ~~each also includes~~ a half-wave plate formed using thin film coating techniques. The Faraday rotator elements are periodically poled in some embodiments using selective poling techniques to create oppositely oriented ~~(bi-directional)~~ magnetic domains so that polarization rotations of 45° in both clockwise and counter-clockwise directions can be simultaneously achieved on the same magnetic garnet. Periodically etched half-wave plates are used in some embodiments. ~~Depending on the orientation of the refraction elements and the optical axes of the first and second PBS elements, the constituents of each polarization orientation element are designed~~

~~**and oriented so that the circulator device achieves a circulating operation with optical signals at an input port, i, coupled to one PBS element being passed to an output port, i+1, coupled to the other PBS element in a non-reciprocal manner.**~~